Experimental Summary

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The goal of this workshop was to further our understanding of the correlation landscape at RHIC with particular emphasis on the meaning of structures on the away side. Near-side correlation and particularly the ridge, focus of a previous BNL workshop, were also discussed at this workshop. An important aspect was to discuss the application of the two-component model for correlations and the use of the Zero-Yield-At-the-Minimum ansatz in extracting correlations related to jets or mini-jets.

1 Observation of Away-side Structures

Angular correlation at low to intermediate p_T and on the away side of high pt trigger particle is broad after flow background subtraction by ZYAM in two-component model. For selected kinematic region, the away-side correlation is even double-peaked. These have been ascribed, among others, to correlations arising from supersonic shock-waves generated by high p_T partons traversing the medium created in heavy-ion collisions.

2 Two-Component Model and ZYAM

Much of our understanding of the correlations have been based on two-component model and ZYAM normalization. “Two-component” refers to two parts of an event, but it is important to clearly define exactly what two parts are being referred to. A dijet produced in a hard-scattering interacts with the medium. The part of the medium that has interacted with the dijet becomes correlated with and an integral part of the dijet. The rest medium that does not interact with the particular dijet (or its corrlated part) does not necessarily possess the regular flow-modulated pattern; it can in principle be any distribution depending on the nature of jet-medium interaction. This part of the medium can only be accessed in theory or models, but not in experiment. Instead, it is decomposed into two pieces, a flow-modulated regular piece and the remaining irregular piece which is treated as an induced signal and combined into the correlated part of the dijet. In the two-component model, one component refers to a regular flow-modulated background, and the other component refers to the sum of correlated and induced signals. Such a separation of two components of the event is well motivated because without jet-medium interaction the background should be the regular flow-modulated distribution.

ZYAM assumes that the correlated and induced signal are both zero at the same angular location. This is a rather strict requirement, so ZYAM is an upper limit and likely invalid. However, within reasonable range it does not affect the correlation shape and therefore serves as a good working assumption to study dihadron correlaitons. This was further substantiated by the "absolute" normalization method shown by PHENIX.

Three-particle ZYAM normalization is lower because richer correlation information is assessable in three-particle correlation. It is likely close to the true background in the measured kinematic range (trigger $p_T = 3 - 4$ GeV/c and assocated $p_T = 1 - 2$ GeV/c by STAR) because it is unlikely to have residual correlation of 4 particles with a leading particle of 3 GeV/c and 3 subleading particles of 1 GeV/c each ($z_T < 0.5$).

Unlike the ZYAM normalization, flow subtraction can affect the shape of jet-like correlation significantly. Assessment of flow systematic uncertainty is crucial, since it can significantly change the away-side structure. The difference in the v_2 explains most of the difference between STAR and PHENIX.

3 SPS Data on the Away-side

Surprisingly, the broad away-side structure is present at SPS energies as well. However, the away-side side shape seems flatter than RHIC data (especially compared to PHENIX), and the shoulder yield is about factor of 2-3 less. These features imply some kind of medium responses at SPS energy that may be different from RHIC. Medium response can not vanish since SPS data still exhibits significant v_2, hence medium collectivity. But whether or not the medium response can be interpreted as Mach cone or pre-Mach cone remain to be studied.

The near-side peak in SPS correlations is much more suppressed relative to RHIC. This is consistent with trigger bias and a rapidly falling jet spectrum. It may also imply that the ridge disappears at SPS. These results clearly warrants further investigation since the precision of the SPS data is limited and trigger bias and particle composition are quite different from RHIC measurements. Understanding the systematics (centrality, pt, etc.) of SPS vis a vis RHIC data will be important. The upcoming RHIC energy scan will allow for the correlations at these energies to be viewed in full $\Delta\phi$ and $\Delta\eta$ space, with particle identification capabilities.

4 Relation of Away-side to the Near-Side ridge

The away-side dip/shoulder structure is mostly prominent in the intermediate p_T range. When associated p_T is lowered, the away-side correlation is still broad but the dip/shoulder structure disappears. Measurements using all unique pairs of charged particles, including p_T values down to the lowest measured in STAR, do not show a Mach-cone like structure on the away-side. However, the ratio of the away to near-side correlation is constant over a large centrality range, suggesting that they may be of the same origin. Furthermore, the width of the near-side peak appears to abruptly broaden at a given centrality; the aspect ratio $\Delta\eta/\Delta\phi$ grows from near 0.7 in $p+p$ collisions to approximately 3 in central Au+Au collisions; the volume of the peaks also increases rapidly in Au+Au collisions, exceeding even $N_{\rm bin}$ scaling. These features call for further investigations.

It was pointed out that the ratio of the number of pairs in the ridge over that in the background is constant over a large centrality range. This could be an indication that the ridge correlations are related to the bulk rather than to an individual hard-scattered parton fragmenting into correlated hadrons. This picture is not inconsistent with the Baryon/Meson ratios in the ridge and shoulder since they are both similar to the bulk and different than the jet-cone. In addition, both the ridge and shoulder have p_T spectra that are softer than spectra from hard scattering although they are harder than the inclusive spectra. It is worth to emphasize that ridge is observed not only in trigger particle correlation but also in all pair correlation. Ridge is unlikely a late stage signal. Many theory models are available; none is conclusive so far.

5 Flow Fluctuation?

The relevance of v_n fluctuations was also brought up. So far, analyses have only considered $\langle v_1^2\rangle$, and even terms, $\langle v_{2n}^2\rangle$, in the description of the background correlations. This is based on the incorrect assumption that $\langle v_n^2\rangle$ has to be zero for odd values of n. This is true on average but fluctuations can occur event-to-event. It was pointed out that much of the complicated azimuthal correlation structure can be easily described in terms of a few harmonics n; particularly the away-side structures which sit at roughly $\pi \pm \pi/3$ independent of centrality and p_T. However, it was pointed out that it was not clear what benefit one gains from this decomposition. The dependence in the longitudinal direction is still an open question.

6 Three-Particle Correlations

Three-particle correlation can unambiguously identify the physics mechanisms underlying the away-side double-peak structure. However, these measurements are difficult to carry out. With the two-component approach, three-particle jet-like correlation results show evidence of conical emission. The p_T-independent emission angle suggests Mach-cone shock-wave being the underlying physics mechanism. On the other hand, a three-particle cumulant analysis in lab-frame azimuthal angle is not conclusive regarding conical emission. Three-particle cumulant is mathematically well-defined; it removes two-particle correlations under the condition of Poisson statistics; and it is additive for multiple processes that are independent. However, due to non-Poisson statistics in real data, the three-particle cumulant does not completely eliminate two-particle correlation effect, and due to interconnected jet and flow, cross terms between jet and flow are present. These are the likely reasons why the three-particle cumulant cannot identify conical emission in the real data. These difficulties can be reduced by using azimuthal angle relative to the reaction plane (i.e., in the natural nuclear collision reference frame), as shown in the published work of three-particle jet-like correlation by STAR. These understandings were confirmed by toy model studies where, when realistic Mach cone signals are simulated, the cumulant analysis does not see them while the two-component three-particle correlation analysis does.

7 Action Items

There is consensus that both (ZYAM) derived and raw correlation data should be published whenever possible. If only derived data are published, experimentalists are obligated to make raw data publicly available. It was also pointed out that data analyses by experimentalists with clear physics motivations and innovative techniques have played a crucial role in the advancement of the field.

The publication of raw correlation functions is perhaps the most straightforward action item identified. In addition, the energy dependence of the correlations appears to be a promising avenue of investigation. More experimental work should be carried out on publishing data and on investigating the correlations as differentially as possible. This includes p_T, charge-sign, particle-type, reaction plane, and $\sqrt{s}$ dependence.